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Virtual Reality in Manufacturing

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Abstract

Virtual Reality (VR) is amongst the technologies that have existed as early as the 1960s. Only until recently it has resurrected and is making a comeback into many shapes and forms of our daily lives. This paper describes in general the use of VR tools in the manufacturing sector. Examples of successful adoption of VR technologies in manufacturing companies and organisations are described. Issues in manufacturing industries revolve around the flow of information and planning processes, intra-organisations and inter-organisations.

Keywords: manufacturing, web-based, virtual reality

1. Introduction

A Virtual Reality (VR) System is a general-purpose simulator (Lanier, 1992) that allows the user to experience an artificially created computer generated environment as if it was real. Elsewhere, Bricken (1992) says that VR is a shared 3-D experience between people and computers with certain unique capabilities that allow for a natural interaction of information between the two systems. It thus can be said that VR is a way for humans to visualize, manipulate and interact with computers and extremely complex data. Visualization is possible through the capability of the computer to generate visual, auditory or other

sensual outputs to the user of a world within the computer. This world may be a CAD model, a scientific simulation, or a view into a database. The user then can interact with the world and directly manipulate objects within the world. Some worlds are animated by other processes, such as physical simulations, or simple animation scripts.

VR is a technology that is often regarded as a natural extension to 3D computer graphics with advanced input and output devices. This technology has only recently matured enough to warrant serious engineering applications such as manufacturing. Applications being developed for VR run a wide spectrum, from games to architectural and business planning. Many applications are worlds that are very similar to our own, like CAD or architectural modeling. Some applications provide ways of viewing from an advantageous perspective not possible with the real world, like scientific simulators, tele-presence systems and air traffic control systems. Other applications are much different from anything one has ever directly experienced before. The ability of VR to provide cost-effective access to high fidelity computer simulations is a very important attribute. The potential of a VR based system is very impressive and as costs for the enabling technologies fall there is likely to be an acceleration in the uses that it will be applied to (Isdale, 1998).

New advances in computerized modeling, visualization, simulation, and product data management are making VR a viable alternative to traditional product realization and manufacturing. Driven by the wider availability of low-cost 3D graphics hardware, and advances in Internet technology that make it easier for even complex information to be disseminated from UNIX workstations to desktop PCs, virtual reality is the wave of the future. It's application in manufacturing enable companies to reduce design and production costs, ensure product quality and slash the time needed to go from product concept to production.

2. Virtual Reality and Virtual Manufacturing

VR is also known as Virtual Environment or Synthetic Environment. By allowing a variety of representations such as 2D or 3D, desktop or immersive, VR can offer users the opportunity to explore virtual objects at levels of detail that are appropriate to work activity. According to (Carr & England, 1995), VR reduces the need for abstract, extero-centric thinking by presenting processed information in an apparent three-dimensional space and allowing user to interact with it as if user were part of that space. In this way the

evolutionarily derived processes of understanding the real world can be used for understanding synthesized information.

Virtual Manufacturing is defined to be an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control (Lawrence Associates, 1995). According to (Marinov, 2001), Virtual Manufacturing is a system, in which the abstract prototypes of manufacturing objects, processes, activities, and principles evolve in a computer-based environment to enhance one or more attributes of the manufacturing process. VR may support the development of enhanced graphic user interfaces (GUIs) for Virtual Manufacturing, and thus, enhance the integration of the human user into a computer system. VR is thus a tool for visualization in Virtual Manufacturing.

3. Virtual Reality applications in Manufacturing

The applications below enlighten the synthetic or virtual manufacturing environment i.e. a system where the abstract prototypes of manufacturing objects, processes, activities, and principles evolve in a computer-based environment to enhance one or more attributes of the manufacturing process.

3.1 Training

VR application in training has been widely used and considered as an advanced method of teaching manufacturing skills and processes to employees. Using cutting-edge VR technology, training takes place in a realistic, simulated version of the actual facility, complete with the actions, sights, and sounds of the plant floor. VR-based training is an option where it is difficult, dangerous, expensive, or impossible to use various real types of training. Such training is also appropriate where there is a large number of employees, where the employees are distributed over a large area, or when it is important that employees get consistent training no matter when or where they take it. There are some skills that are learned better by experiencing realistic settings than from a lecture, demonstration, or book. Optimal training occurs when each employee is allowed complete access to the entire facility. VR-based manufacturing training duplicates an entire continuous manufacturing process, giving each trainee their own factory to learn in.

All employees are also able to practice existing and new tasks in safe, simulated environment, and see how a product takes shape as it moves through the manufacturing system. By giving employees repeated exposure of their operating environment, they become acutely more aware of the methodology, equipment, structure, and goals of the manufacturing process. Training in a virtual reality version of plants not only familiarizes employees with individual responsibilities, but the entire facility, providing them with an excellent understanding of how they fit into the entire process, greatly improving the overall efficiency of the plant. Any process can be replicated, creating a superior environment for employees to understand manufacturing processes and issues.

Companies such as Motorola, Samsung, IBM and Lucent Technologies have opted for PC-based VR simulations developed by Modis Training Technologies to aid in their training effort. Using Superscape, a VR software, training courses were created that simulate wafer inspection and handling, microelectronics and cleanroom procedures. The applications were networked, making it possible to provide the same VR-based training for all company employees. Employee performance can also be recorded on PCs used in training, then evaluated by the management (Mark H., 1998).

Lucent Technologies, a manufacturer of integrated circuits, has worked with Modis to develop several VR training modules. This courseware enables trainees to understand and practice the precise sequence of steps needed for several semiconductor manufacturing processes, from operating ion-implant equipment to thin-film processing for building an integrated circuit. Workers can go through the simulation when they have time and then use it periodically as a reference tool in solving problems.

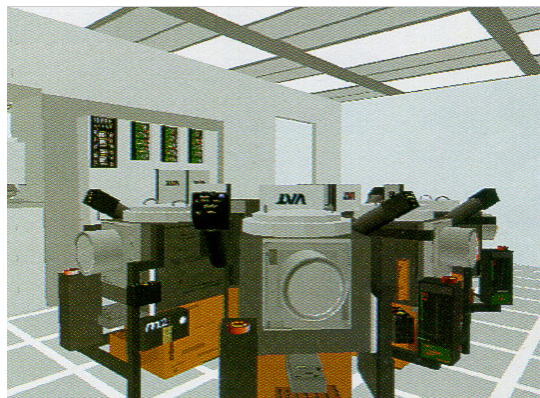


Figure 1: Virtual clean-room. Part of a VR training course developed by Modis for Lucent Technologies (Mark H., 1998).

3.2 Assembly

A natural evolution of CAD technology is the addition of VR functionality to design systems. This new functionality provide designers with methods that will extend their ability in the development of new and variant products. The design process itself will change to accommodate this new view of the product and the processes that are used to fabricate it. It is purported that once VR technologies are used widely in industry, new approaches to design, as well as the associated business and engineering processes, are likely.

Technologies that allow for virtual assembly evaluation and analysis are not yet fully utilized by industry. Although this emerging technology is not completely understood in regards to applications within commercial industries, the technology as a whole is viewed as viable and valuable. Virtual assembly (VA) is a key component of virtual manufacturing and is defined as:

“The use of computer tools to make or “assist with” assembly-related engineering decisions through analysis, predictive models, visualization, and presentation of data without physical realization of the product or supporting processes.” (S. Jayaram, 1997)

VA, although defined as a technology, is actually a combination of several technologies such as advanced visualization, simulation, decision theory, assembly and manufacturing procedures, and assembly/manufacturing equipment development.

The Virtual Assembly Design Environment (VADE) which has been designed and implemented at Washington State University in collaboration with National Institute of Standards and Technology is a VR-based engineering application that allows engineers to evaluate, analyze, and plan the assembly of mechanical systems. This system focuses on utilizing an immersive, virtual environment tightly coupled with commercial computer aided design (CAD) systems.

Salient features of VADE include, data integration (two-way) with a parametric CAD system, realistic interaction of user with parts in the virtual environment, creation of valued design information in the virtual environment, reverse data transfer of design information back to the CAD system, significant interactivity in the virtual environment, collision detection and physically-based modelling. In the virtual environment, the user is presented with an

assembly scene. The various parts are initially located where they would be in the real assembly plant. The user can then perform the assembly. This enables the user to make decisions, make design changes, and perform a host of other engineering tasks in the virtual environment. During this process, the virtual environment maintains a link with the CAD system and uses the capabilities of the CAD system wherever required.

In 1995, Ford initiated the C3P project designed to make extensive use of advanced computer technology, virtual reality (VR) being one example, to aid in the design and assembly of Ford vehicles (Ressler,1994). C3P is a combination of computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), and a massive product information management (PIM) database that is proprietary to Ford. C3P's truly amazing digital capabilities means Ford can be not only quicker to develop new vehicles, but achieve even higher levels of quality. The first Ford to be created digitally using C3P is the Mondeo. The new Ford Mondeo's precision and quality were achieved with the help of this revolutionary new integrated engineering tool set and processes method. C3P helps Ford in reducing thirteen months of Mondeo's development process.



Figure 2: Mondeo - The first Ford to be created digitally. (Ford Media Website, 2001)

3.3 Design

3.3.1 Virtual Prototyping

Virtual prototyping is a software-based engineering discipline that entails modeling a mechanical system, simulating and visualizing its 3D motion behavior under real-world operating conditions, and refining/optimizing the design through iterative design studies prior to building the first physical prototype.

Today, manufacturers are embracing simulation in their design process for a number of reasons: to cut down on the number of physical prototypes they need to build, to shave time from design schedules, and to make better products. Virtual prototyping enable designer to simulate not just the way things look but also the way things work. Designers can use virtual prototyping to check the operation and viability of new objects or assemblies by building them as a computer model before going to the expense and trouble of making physical models of them. 3D CAD models may be given attributes such as appearance, motion, strength, wear resistance, heat conduction, and flexibility, then placed in a computer environment that simulates anticipated conditions and interactions. This computer prototype can then be used to identify potential problems in a faster, less expensive, and safer way than with traditional physical prototypes, thus shortening design cycle times and reducing overall costs.

Virtual prototyping software uses real-time, 3D technology to simulate the operation and maintenance of virtual prototypes. This software can provide a simulated virtual manufacturing environment to develop and optimize fabrication, assembly, machining, and other manual and robotic manufacturing processes, eliminating the need for physical product prototypes or production tooling mock-ups. Virtual prototyping can be used to model the work flow, facility layout, throughput, line balancing, and product cost.

The existence of a virtual prototype offers some advantages and capabilities over a real prototype. One of the most crucial is the ability to have real-time, non-intrusive instrumentation, which allows the engineer to monitor the state of a system without producing unwanted modification to its operation. In addition, it provides much greater levels of visibility than can be obtained from a real system.

Intelligence Systems Solutions (ISS) Ltd. Of Salford, England has developed a VR demonstrator for London-based Rolls-Royce Aero Engine Services Ltd. for the company's Trent 800 engine, which is used in the Boeing 777. The demonstrator was a basic VR unit that enabled Rolls-Royce to plug its CAD data into the VR system, tag certain items, like bolts with functionality, and then pick up a tool and try to hit those bolts. Users of the VR system could also remove brackets and pipes from the engine. This type of virtual interaction with the engine under design, without a prototype physically being built, allowed Rolls-Royce to make an assessment of how easy it would be to build the engine and maintain it (Greenfield,1996)

3.3.2 Virtual Factory

When designing a production facility, many complex factors need to be considered. First, there is the physical space required for each piece of equipment and its operators. Then, the space required for maintenance, loading/unloading, utilities, debris removal, tool storage, and inspection must be added. After considering lighting, product flow, machine capacities, the variety of expected applications, and the order of operations performed, an optimum position for the equipment may be selected. This process is complicated enough for one machine, but when several machines are considered at once it can be overwhelming. Incorrect placement can make a plant inefficient. If all of the critical factors are modelled into a computer simulation, visualization of trade-offs and the impacts of options become much easier.

According to Technical Insights Inc. (1998), a virtual factory on a computer enables user to analyze and pinpoint flaws in the manufacturing process before they occur on the actual factory floor. User will learn the elements that make up the environment and how to make them all work smoothly together to:

- create a computer-based environment that accurately simulates individual manufacturing processes and total manufacturing enterprises,
- reduce manufacturing costs,
- shorten development time,
- optimize time to market;
- smoothly integrate product, process, and resource design,
- produce accurate, early assessments of producibility and affordability, and
- develop seamless information transfer

Engineering Animation, Inc. EAI, a developer of world-class visualization, collaboration and analysis tools has developed a comprehensive virtual factory solution to help manufacturing organizations design better systems faster. Incorporating process planning, factory modelling, ergonomics, factory viewing, and web-driven design review, the virtual factory software improves manufacturing processes from process planning to the final design.

Using the virtual factory applications, companies can design factory layouts and plan manufacturing processes that dramatically improve productivity and decrease time-to-launch (UGS Website, 2001). This solution visually integrates an enterprise's complete manufacturing process, from initial product design to final production which reduces overall production planning time, decreases the resources needed to bring a product to market and dramatically improves production line efficiency (Techmall Website, 2001).

Engineers at the University at Buffalo have developed a new virtual factory software known as VR-Fact. The software enables the user to walk through an assembly plant that hasn't been built yet and moving around heavy pieces of equipment just by pointing and dragging the mouse. VR-Fact provides companies with a three-dimensional method of virtually designing large-scale plants and simulating work within them. The simulations, in turn, allow manufacturers to do such things as identify and avert potential bottlenecks long before breaking ground for a new plant. Other features of the software include automatic generation of most standard machines using the process parameters, detection of ergonomic problems, monitoring of shopfloor activities and interfaces with database systems.



Figure 3: Virtual Factory (<http://www.vrlab.buffalo.edu>).

4. Web-based Virtual Reality

Web-based systems provide an excellent tool for sharing virtual models or environment with remote users and for supporting collaborative work (Beier, 2000). Web-based VR systems are thus cost effective since the required infrastructure exists almost everywhere and the viewing software (plug-in) is freely made available to everyone.

Beier further suggests a potential solution for a standardized virtual model is the use of Virtual Reality Modelling Language (VRML). While HTML, the HyperText Markup Language, is the current standard for authoring home pages, VRML supports the distribution of three-dimensional models over the Internet. These models are based on a polygonal representation and can be animated, can include functionality and dynamic behavior, and can be interactively controlled by the user.

5. Conclusion

This paper presents the concept and applications of virtual reality in manufacturing. The benefits of using VR in manufacturing have been highlighted and some potential areas of VR applications in manufacturing have been discussed. VRML which has been developed for Internet and WWW currently represents the most important way to deliver three-dimensional objects to the screen of arbitrary user. It enables three-dimensional objects to be presented and their behavior simulated. Lot of manufacturing applications can benefit from the VRML features in terms of presenting new models, optional designs, and various objects with different functionality (George McKee,2001).

It is important to realize that VR is not merely for visualization purposes, instead, offers improved methods of interaction and visualization, where it can be applied in real engineering problems.

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